

113

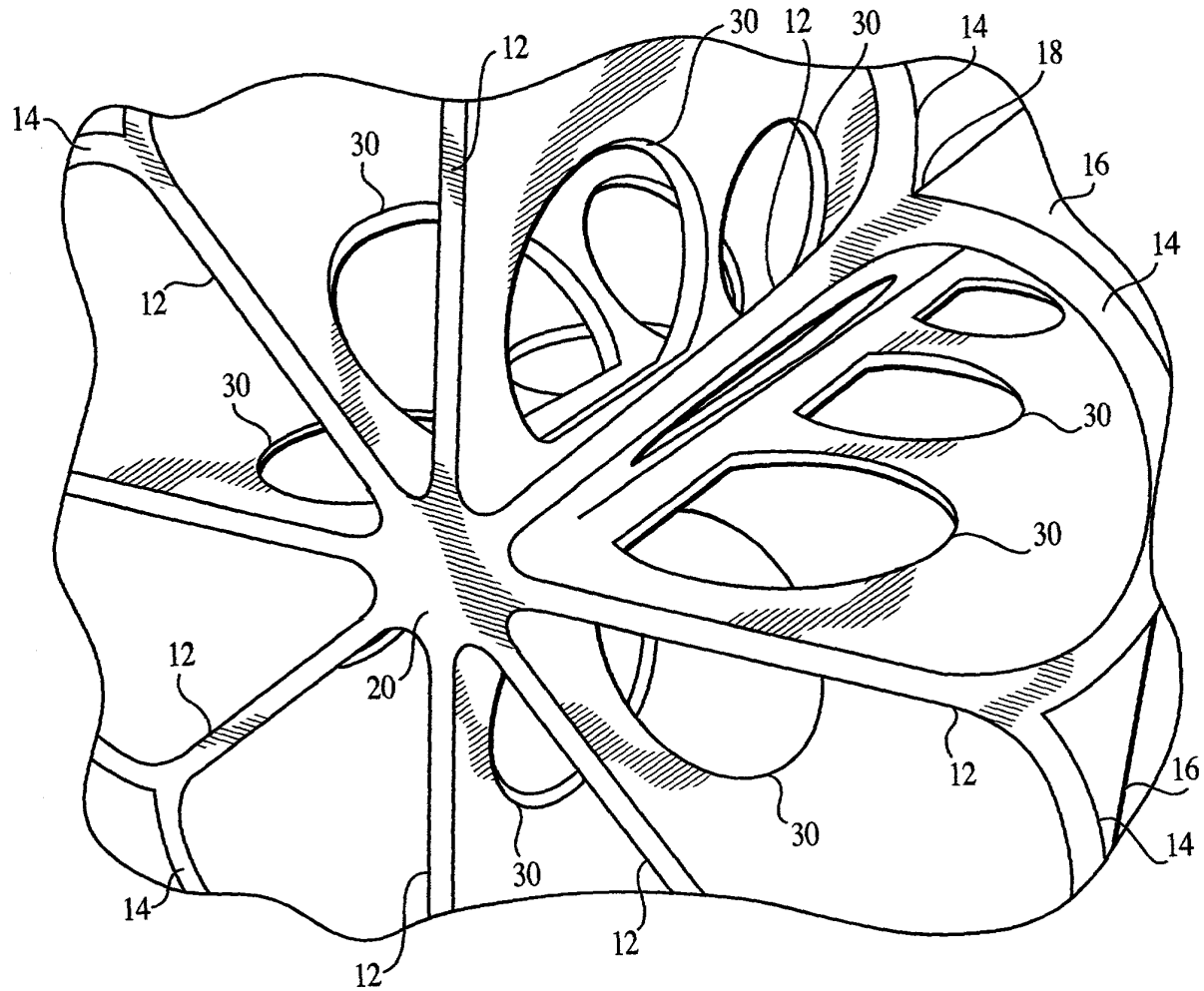
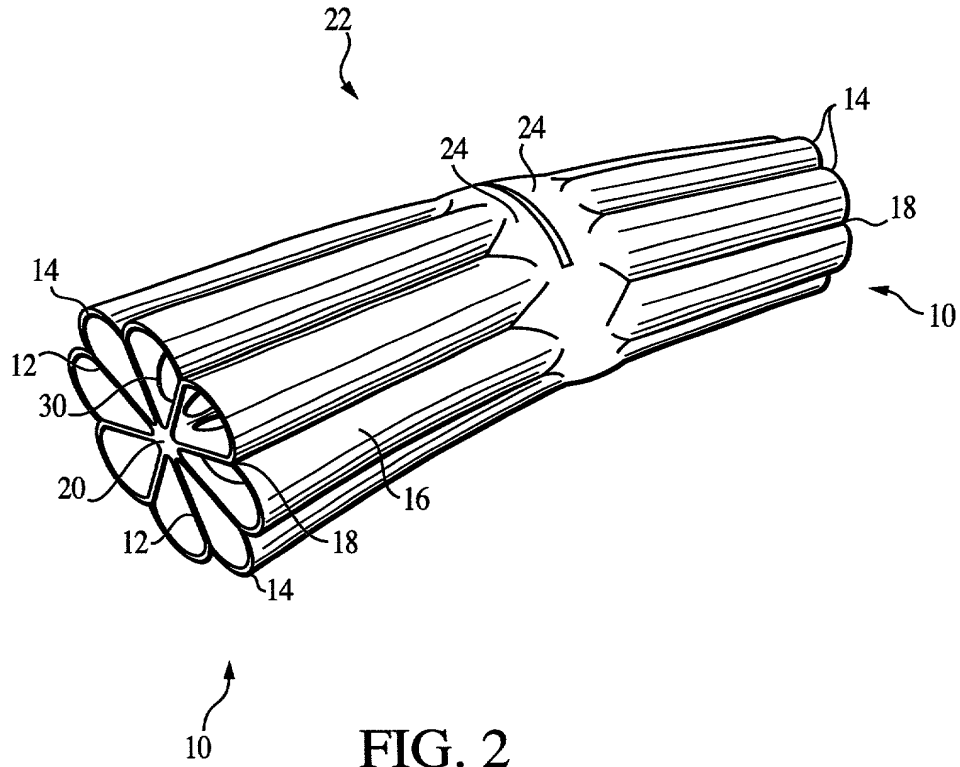


FIG. 1

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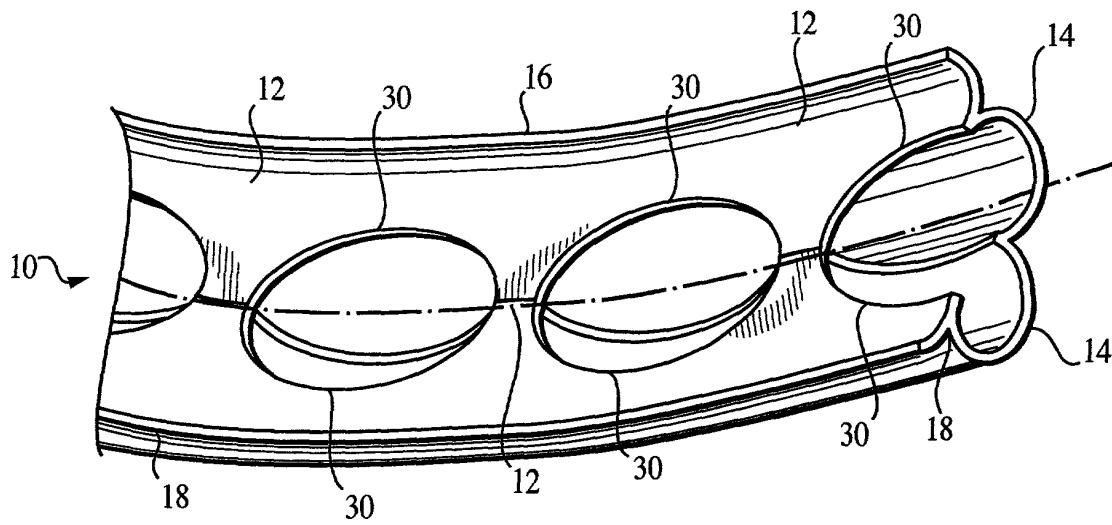


FIG. 3

10021930.060402

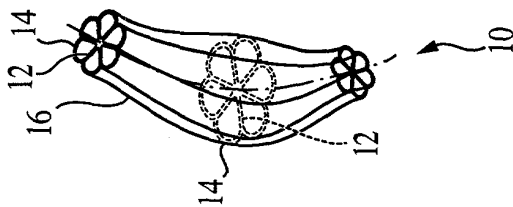


FIG. 4A

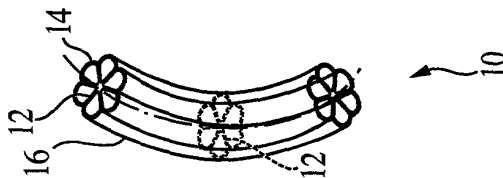


FIG. 4B

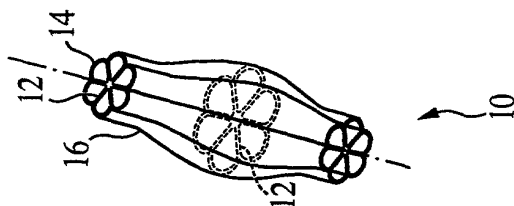


FIG. 4C

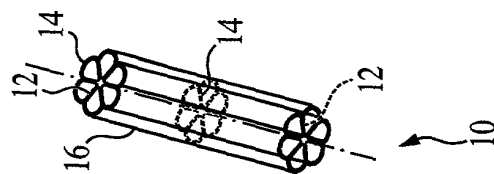


FIG. 4D

2010930" DEBT2001

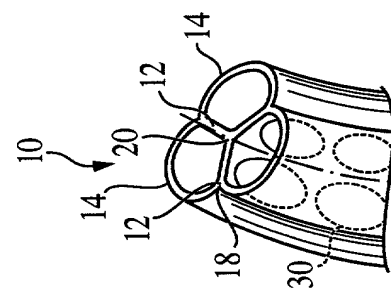


FIG. 5A

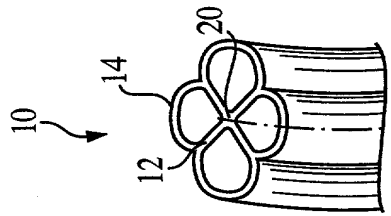


FIG. 5B

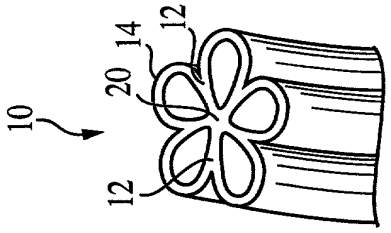


FIG. 5C

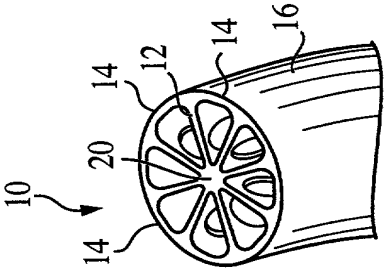


FIG. 5D

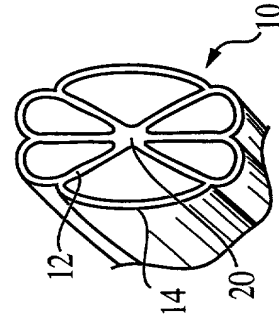


FIG. 6A

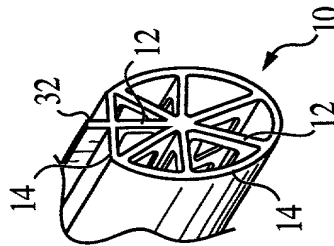


FIG. 6B

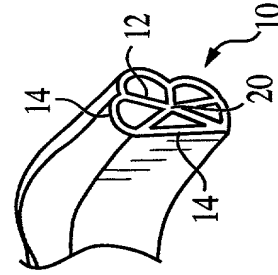


FIG. 6C

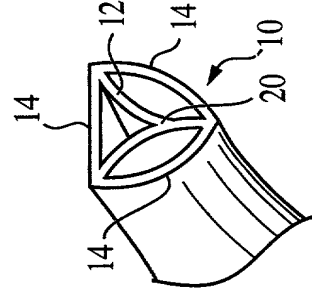


FIG. 6D

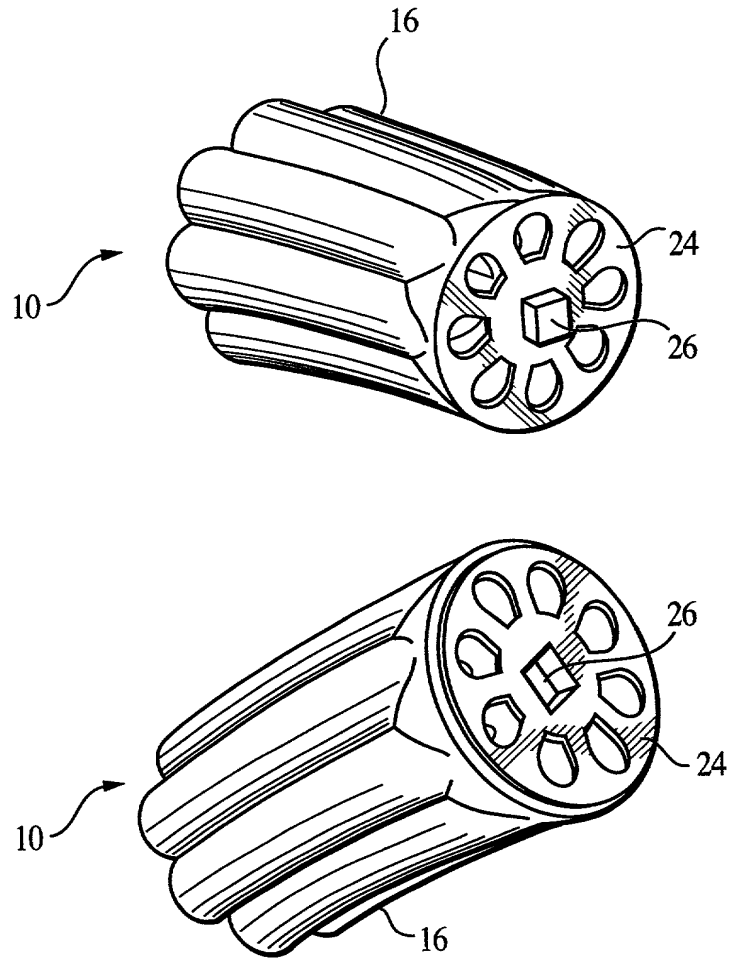
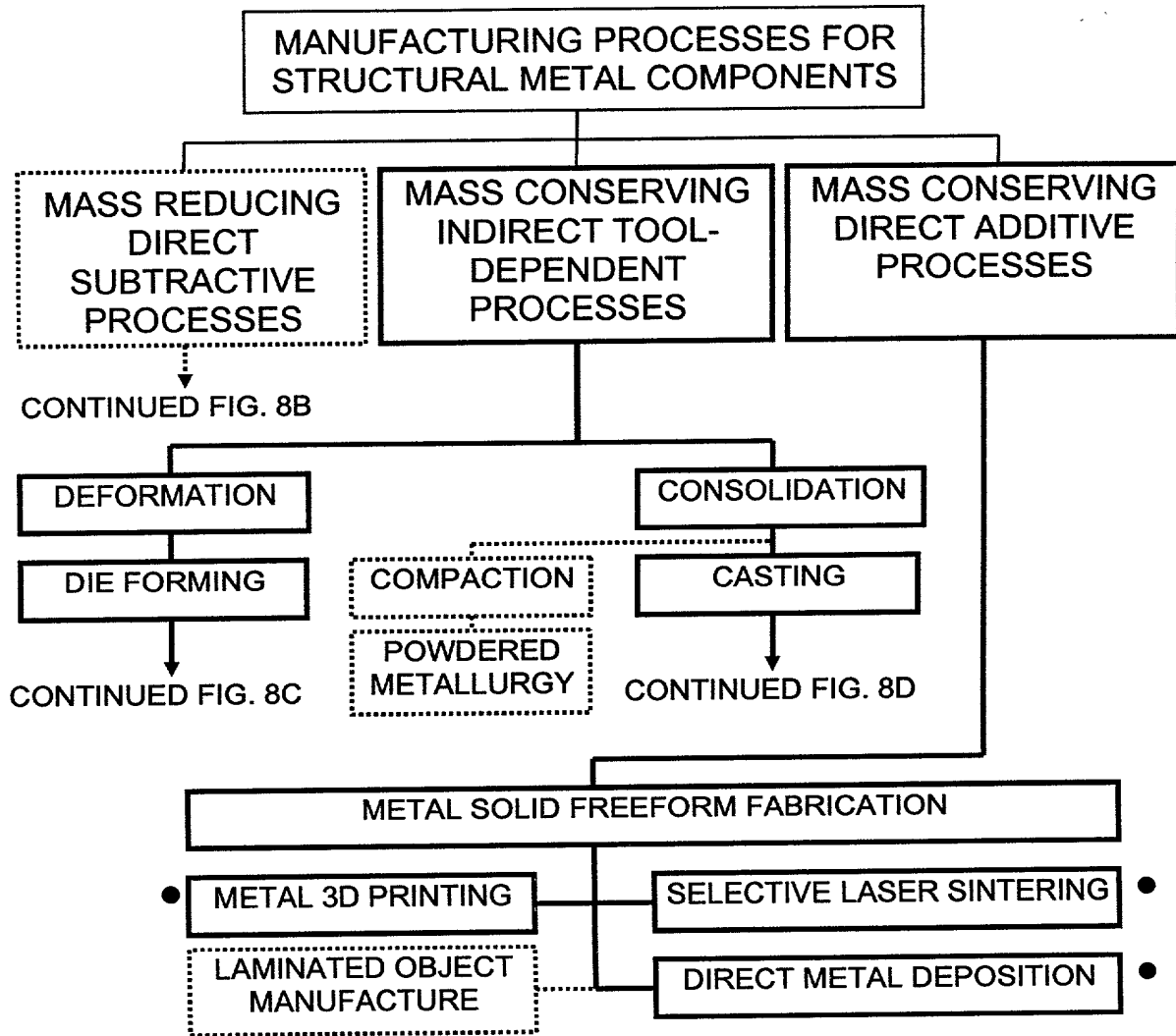


FIG. 7

FIG. 8A

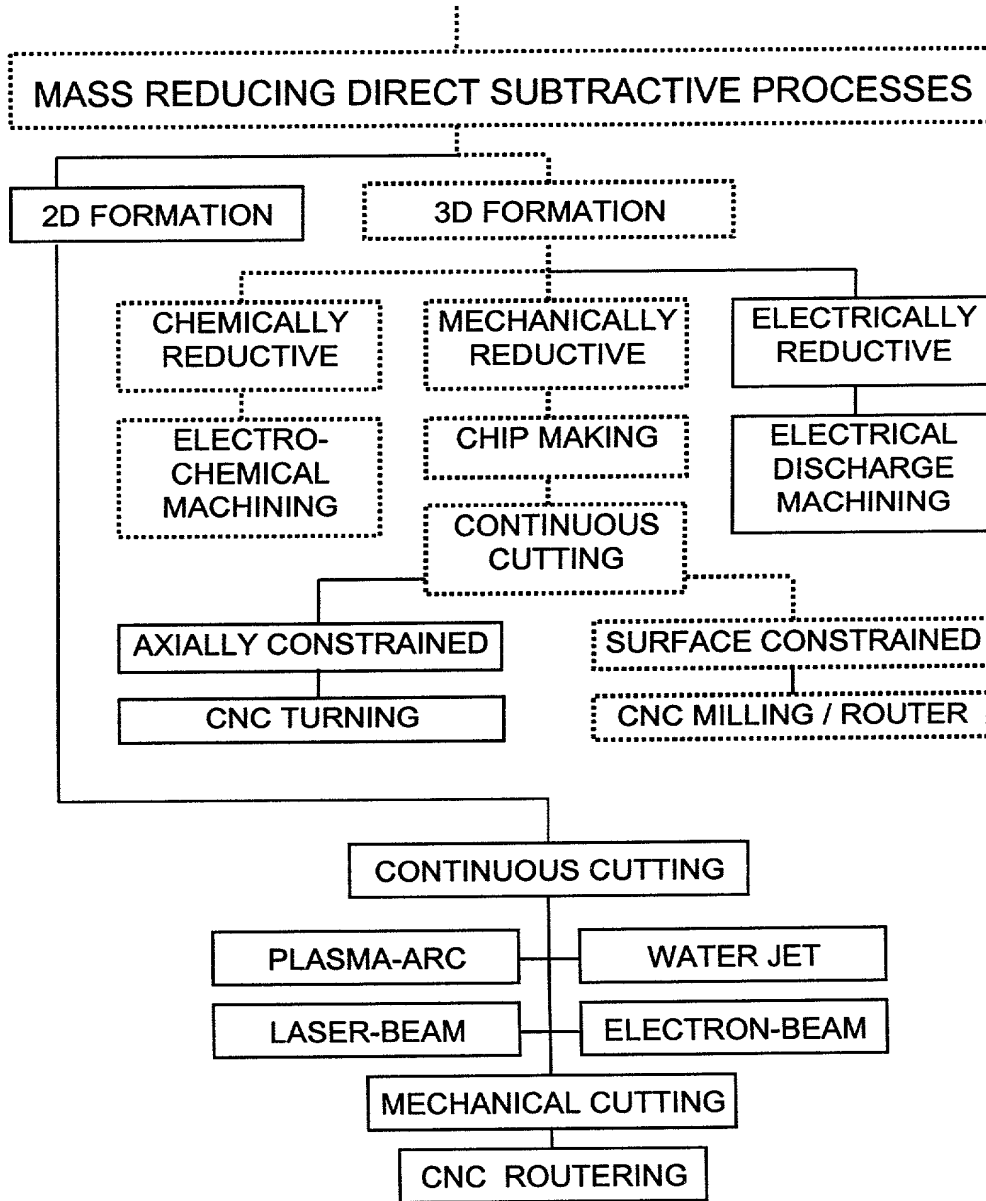


LEGEND

- PROCESS WITH NO CAPACITY TO PRODUCE COMPLEXLY-SHAPED SOLID COMPONENTS.
- PROCESS CAPACITY TO PRODUCE COMPLEXLY-SHAPED TUBULAR AS WELL AS SOLID COMPONENTS.
- PROCESS WITH CAPACITY TO PRODUCE COMPLEXLY-SHAPED TUBES WITH VERY LIMITED INTERNAL FEATURES.
- PROCESS WITH CAPACITY TO PRODUCE COMPLEXLY-SHAPED TUBES WITH EXTENSIVE INTERNAL FEATURES.
- PROCESS WITH NO CAPACITY TO PRODUCE COMPLEXLY-SHAPED SOLID OR TUBULAR COMPONENTS.

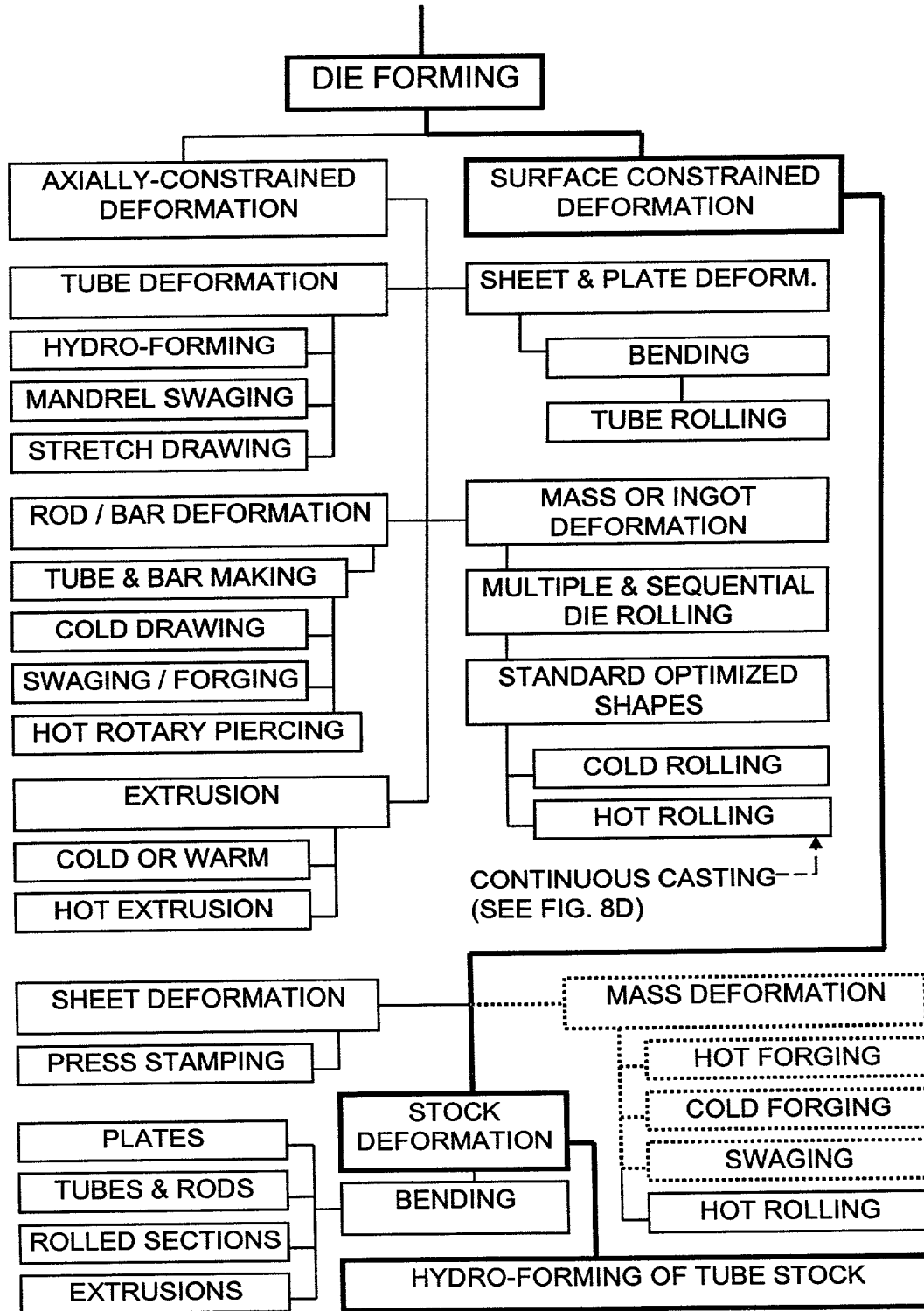
20140901 00:00:00

FIG. 8B



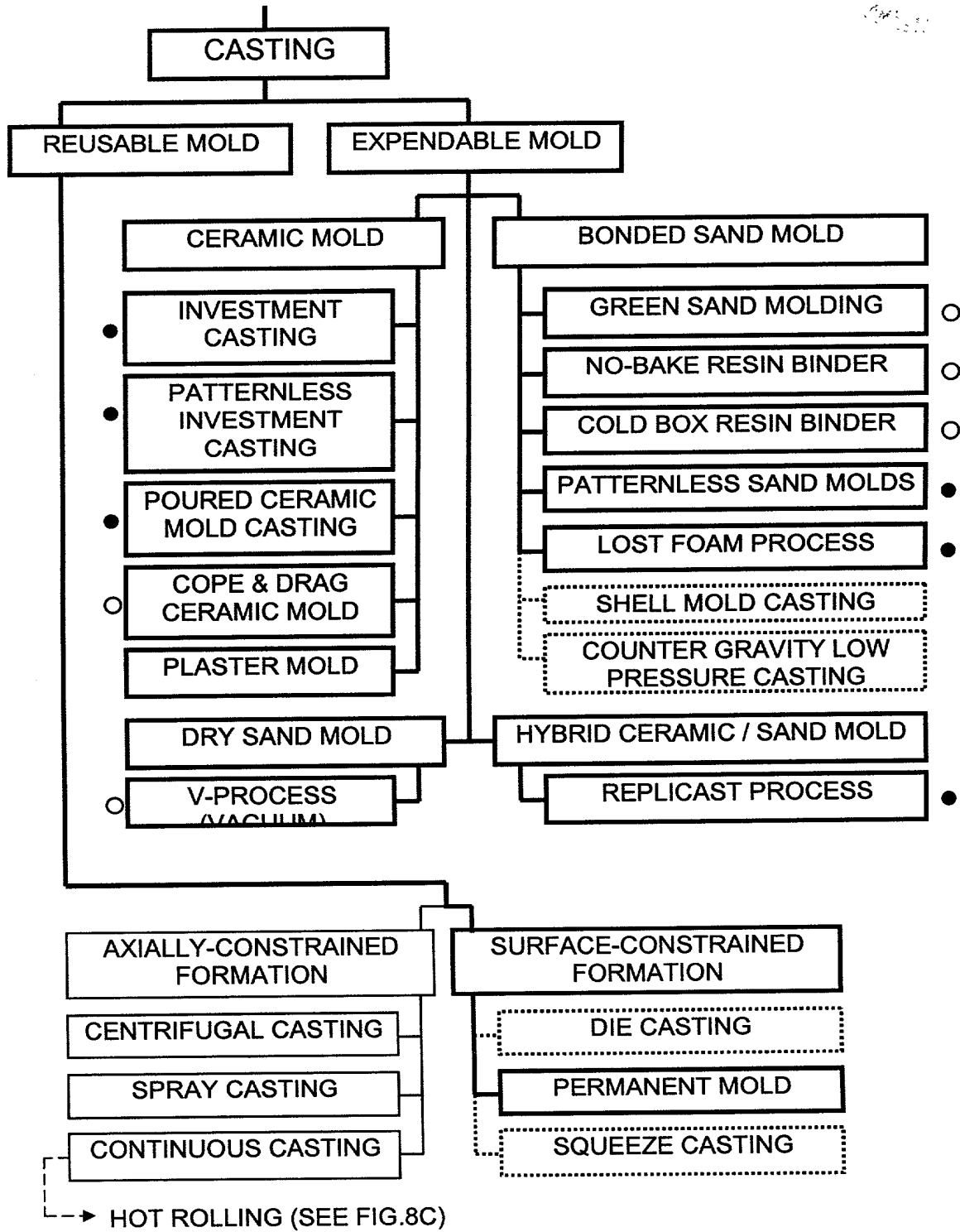
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FIG. 8C



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FIG. 8D



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Tooling Classification						Process Status		Fundamental Computer-Aided Manufacturing Processes for Complexly-Shaped Metal Structural Components:										Capacity to Produce Freeform Components:		Complexity-Shaped Solids			
Hand Die	Hard Mold	Soft Mold	Expendable Mold	Hard Pattern	Expendable Pattern	No Tooling	Established	Emerging	R & D											Capacity	Unfilled Capacity	Freeform Tubes	Tubes with Internal Features
										Direct Production Processes:													
										1	3D Data	Additive Formation	Component										
										2	3D Data	Subtractive Formation	Component										
										Direct Expendable Mold Processes (Direct Tooling):													
										3	3D Data	Additive Formation	Expendable Mold	Component									
										4	3D Data	Subtractive Formation	Expendable Mold	Component									
										Indirect Expendable Mold Processes:													
										5	3D Data	Additive Formation	Expendable Pattern	Expendable Mold	Component								
										6	3D Data	Subtractive Formation	Expendable Pattern	Expendable Mold	Component								
										7	3D Data	Subtractive Formation	Permanent Mold	Expendable Pattern	Expendable Mold	Component							
										8	3D Data	Additive Formation	Net Shape Mold	Subtractive Formation	Permanent Mold	Expendable Pattern	Expendable Mold	Component					
										9	3D Data	Additive Formation	Master Pattern	Expendable Mold	Component								
										10	3D Data	Subtractive Formation	Master Pattern	Expendable Mold	Component								
										11	3D Data	Additive Formation	Master Pattern	Short-Life Mold	Expendable Pattern	Expendable Mold	Component						
										12	3D Data	Subtractive Formation	Master Pattern	Short-Life Mold	Expendable Pattern	Expendable Mold	Component						
										Direct Permanent Mold Production Processes:													
										13	3D Data	Additive Formation	Permanent Mold	Component	<i>Note: Permanent mold processes have the capacity to produce freeform metal tubes if sand cores are used, which is an established method. As with other pattern & mold-based processes, the capacity to produce internal features is limited by pattern or product removal.</i>								
										14	3D Data	Additive Formation	Net Shape Mold	Subtractive Formation	Permanent Mold	Component							
										15	3D Data	Subtractive Formation	Permanent Mold	Component									
										Direct Permanent Die Production Processes:													
										16	3D Data	Additive Formation	Permanent Die Set	Component									
										17	3D Data	Additive Formation	Net Shape Die Set	Subtractive Formation	Permanent Die Set	Component							
										18	3D Data	Subtractive Formation	Permanent Die Set	Component									
										Indirect Permanent Die Production Processes:													
										19	3D Data	Additive Formation	Expendable Pattern	Expendable Mold	Net Shape Die Set	Subtractive Formation	Permanent Die Set	Component					
										20	3D Data	Subtractive Formation	Expendable Pattern	Expendable Mold	Net Shape Die Set	Subtractive Formation	Permanent Die Set	Component					
										21	3D Data	Subtractive Formation	Expendable Mold	Net Shape Die Set	Subtractive Formation	Permanent Die Set	Component						
										22	3D Data	Additive Formation	Master Pattern	Expendable Mold	Net Shape Die Set	Subtractive Formation	Permanent Die Set	Component					
										23	3D Data	Subtractive Formation	Master Pattern	Expendable Mold	Net Shape Die Set	Subtractive Formation	Permanent Die Set	Component					

FIG. 9

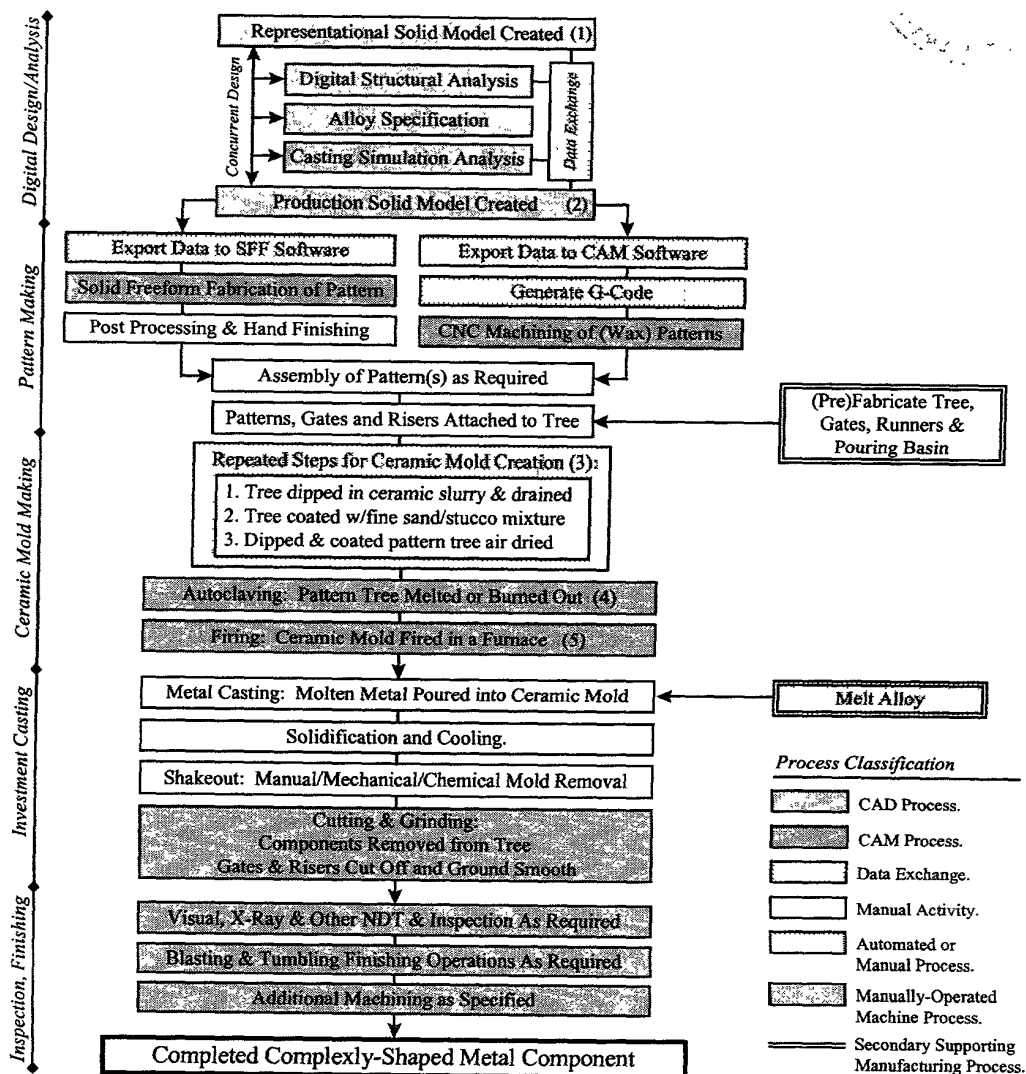


FIG. 10

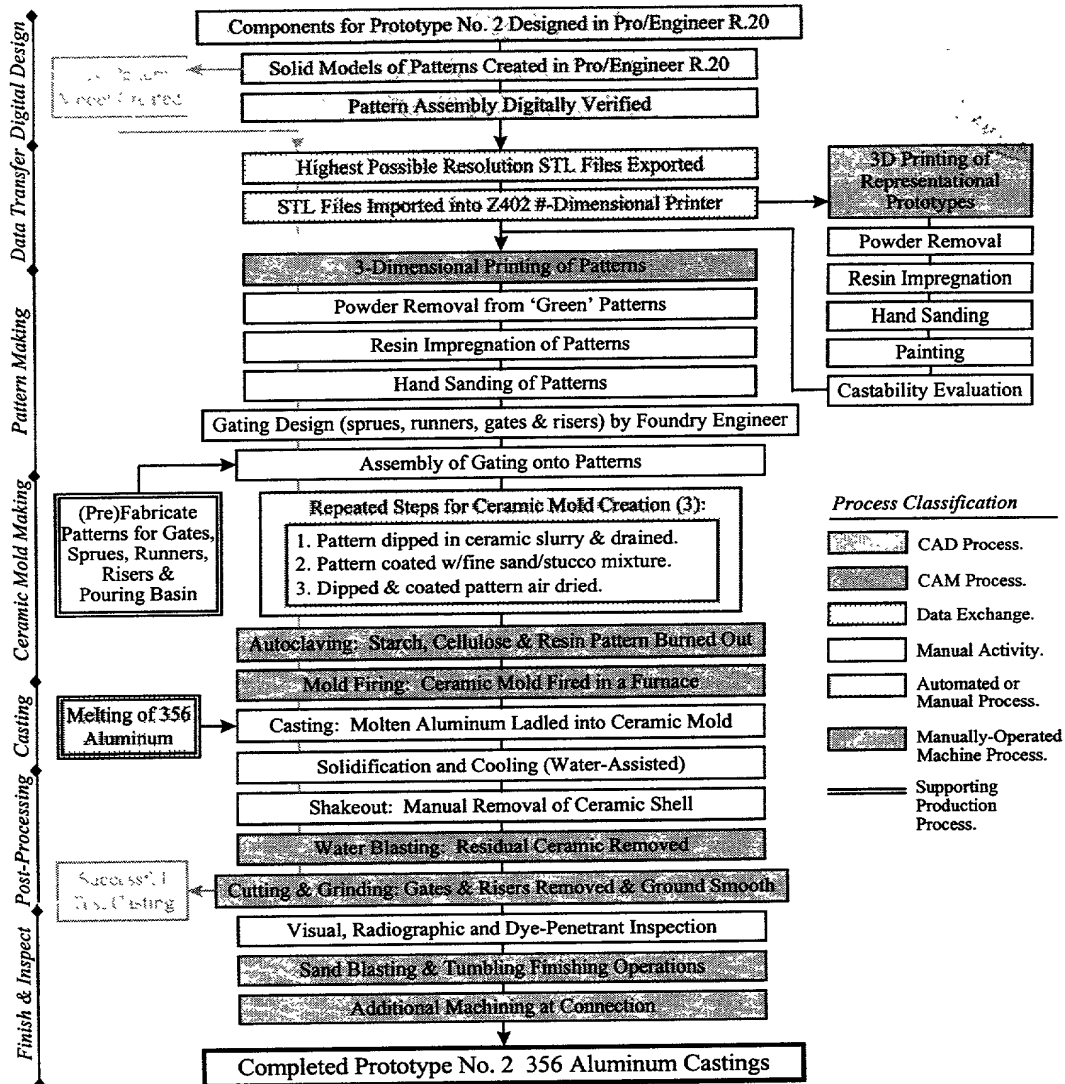


FIG. 11

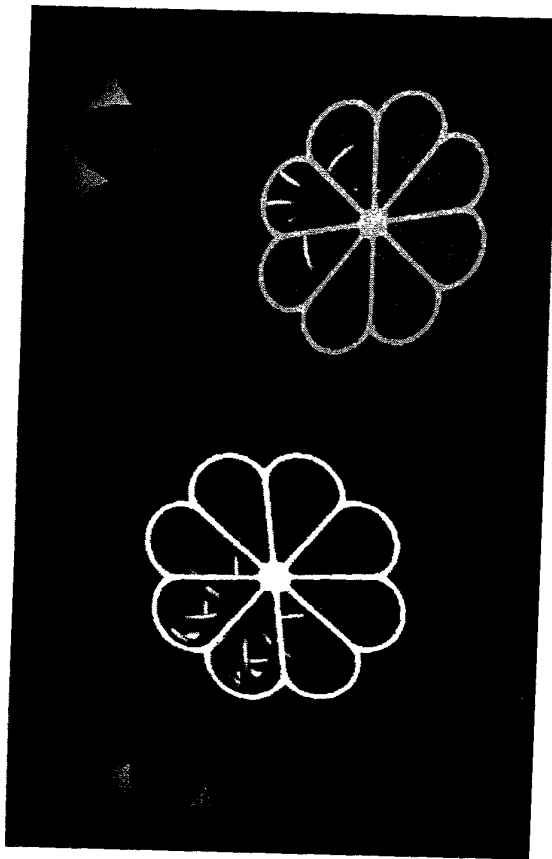


FIG. 12

10021930.060402

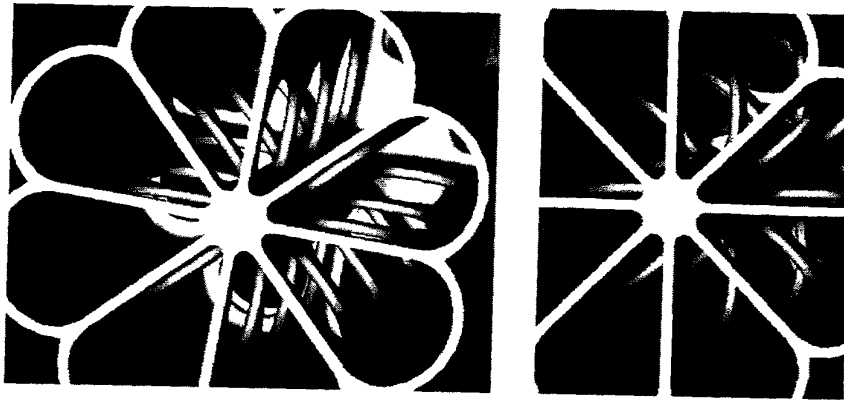


FIG. 13

204090-060402

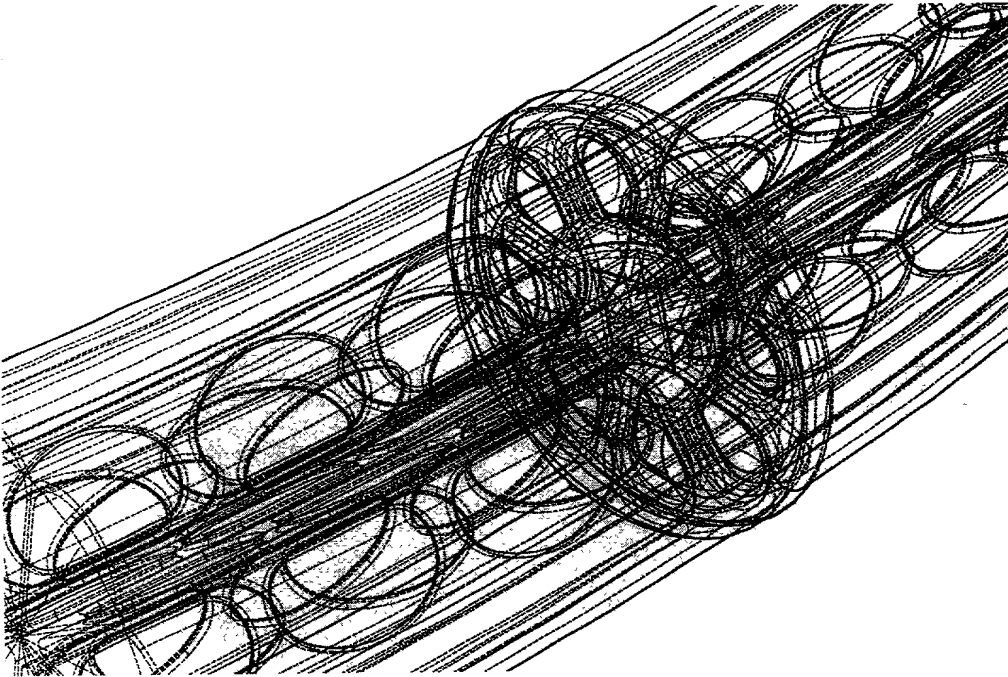
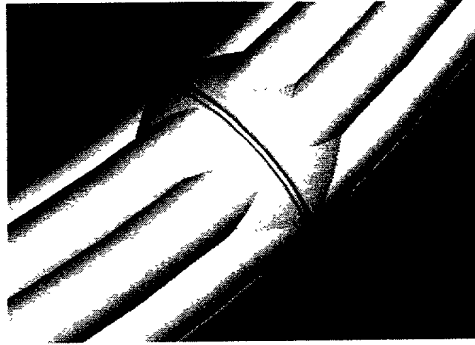
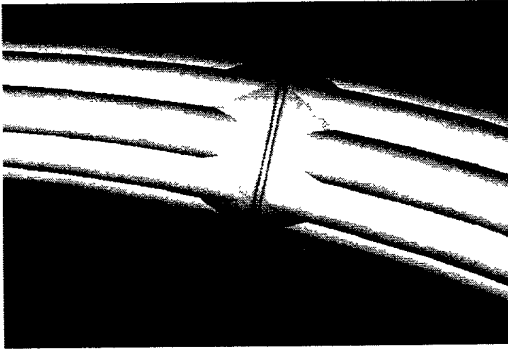


FIG. 14

204090-05612001

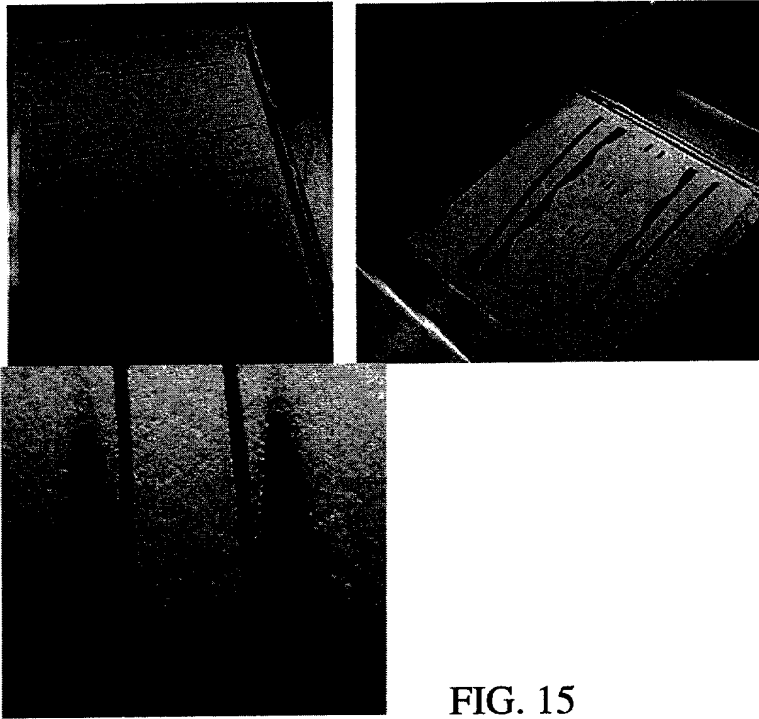


FIG. 15

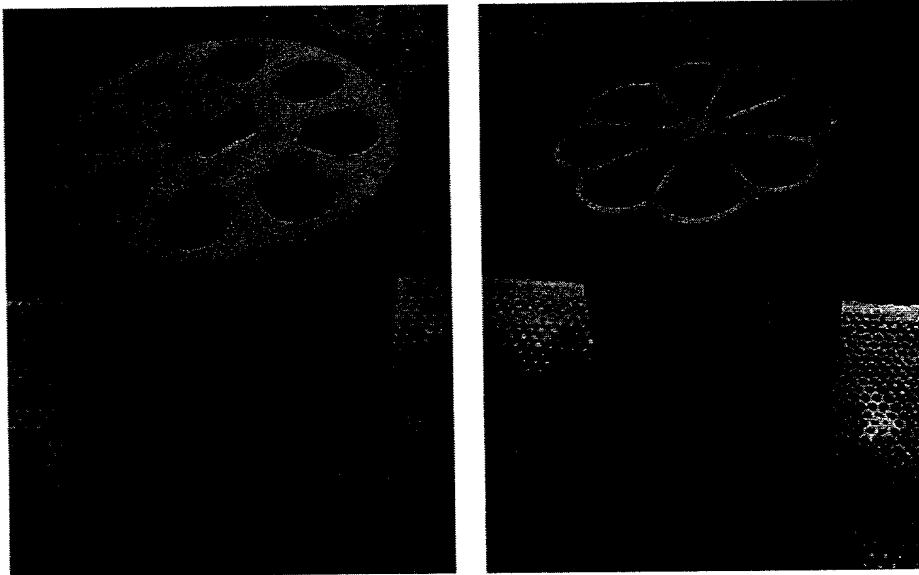


FIG. 16

204090" 05612001

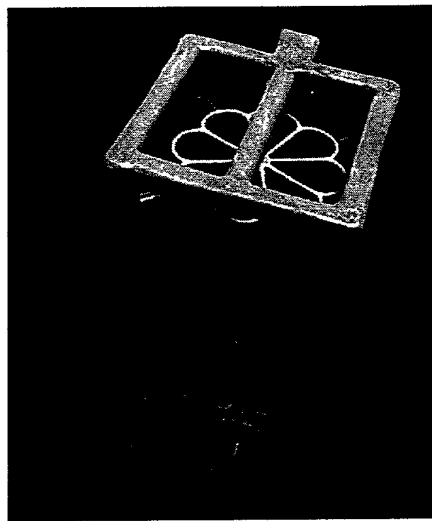
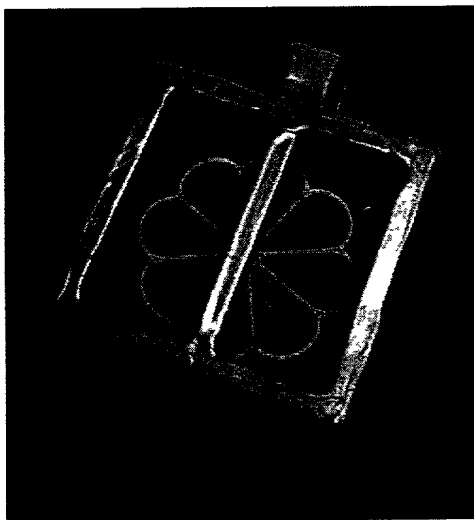


FIG. 17

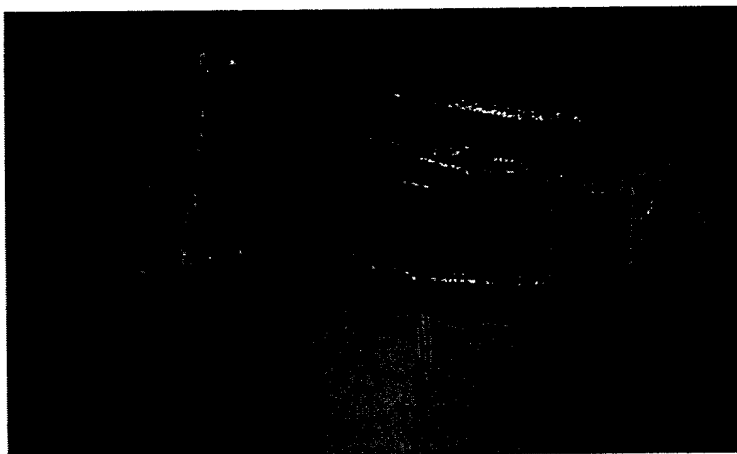


FIG. 18

204090" 056T200T

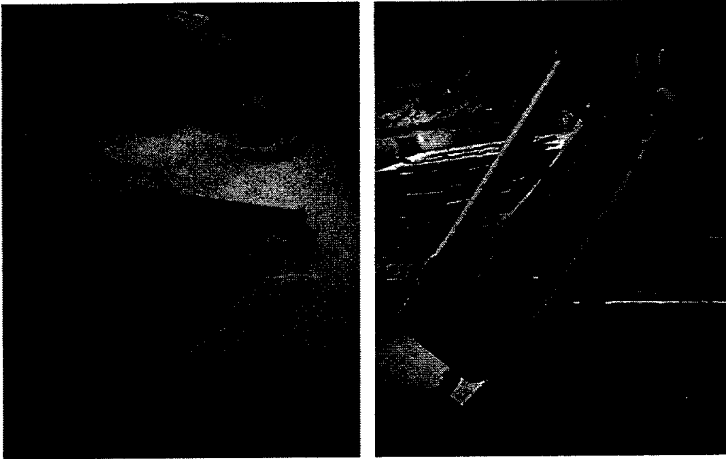


FIG. 19

10021930.060402

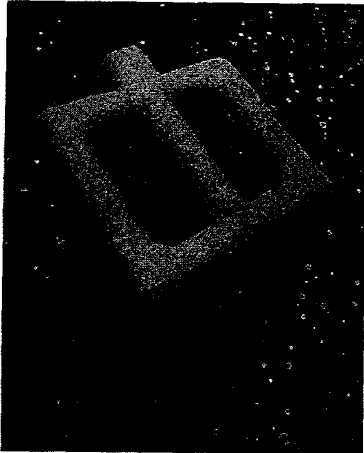
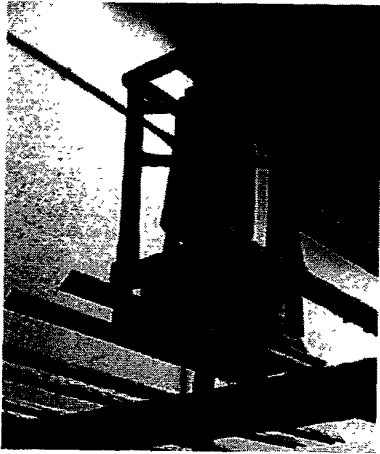


FIG. 20

10021930.060402

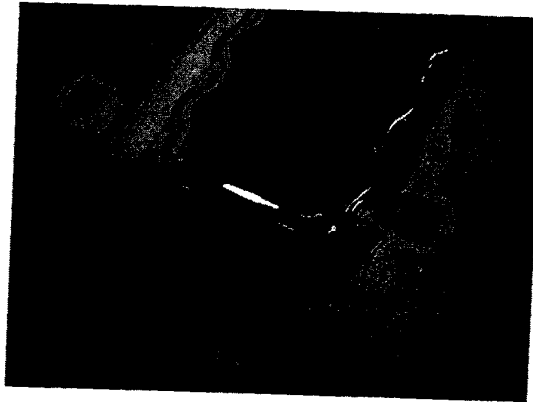
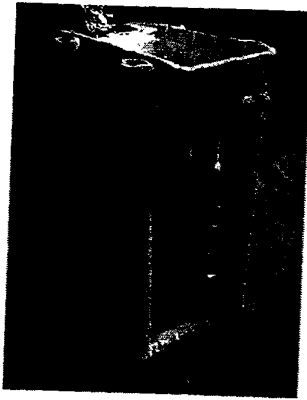


FIG. 21

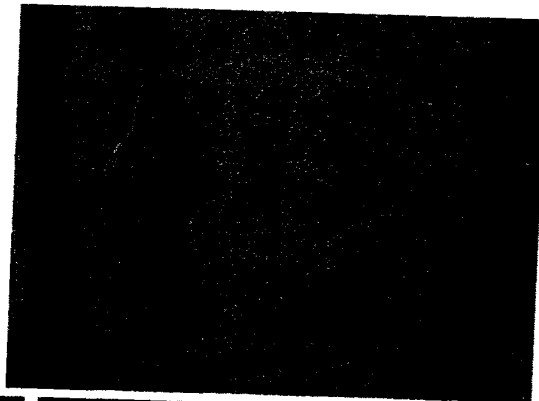


FIG. 22



FIG. 23

204090-06612001



FIG. 24

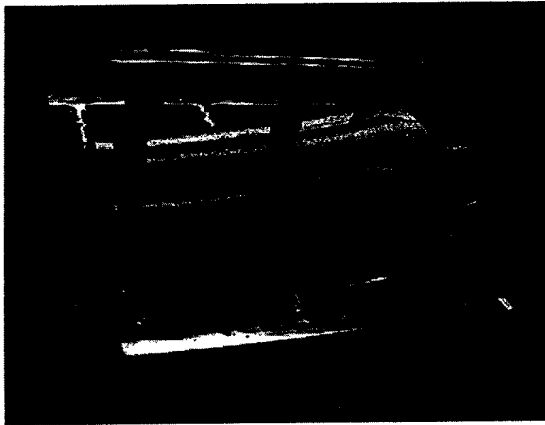


FIG. 25

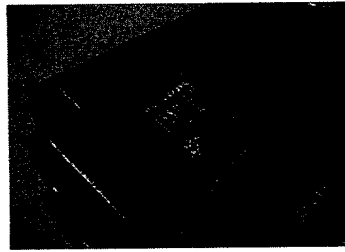


FIG. 26

10021930-060402



FIG. 27

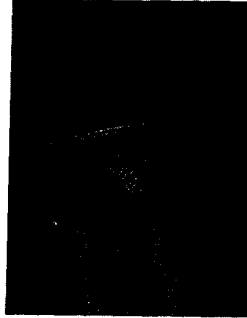


FIG. 28



FIG. 29

204090-06512001

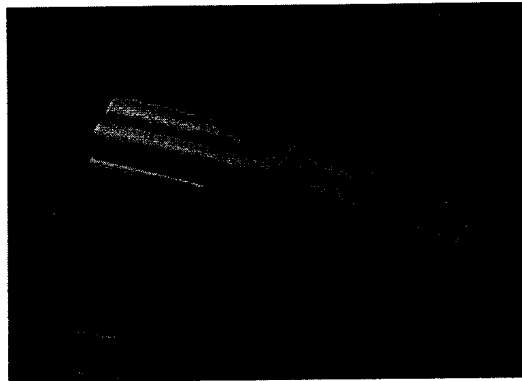
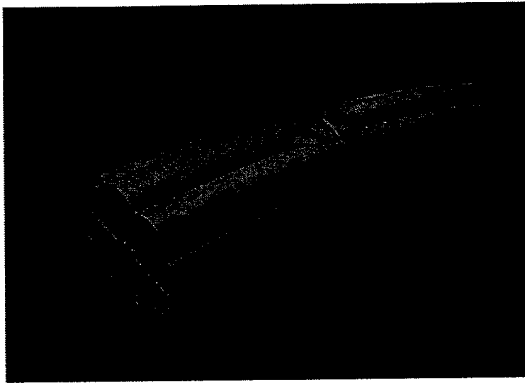
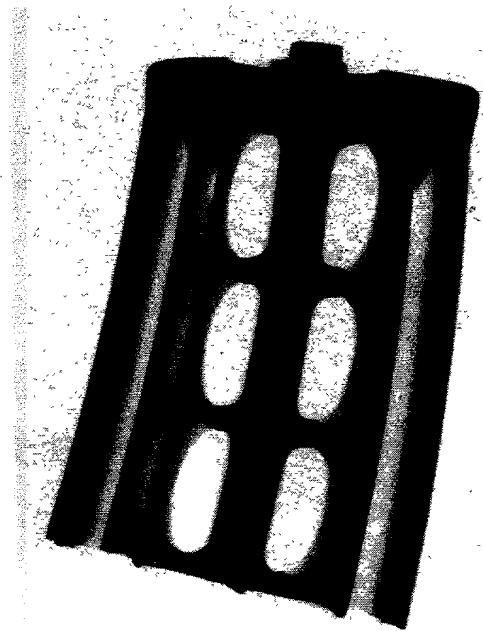
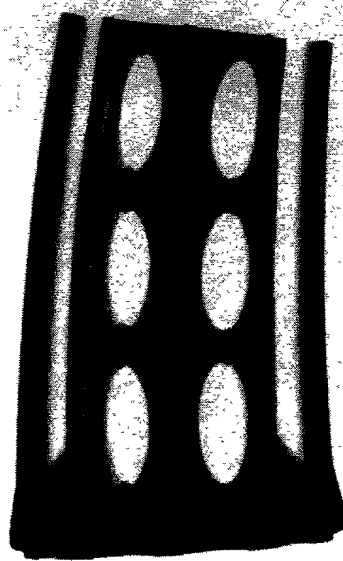


FIG. 30



31A



31B

FIG. 31

10021930-060402

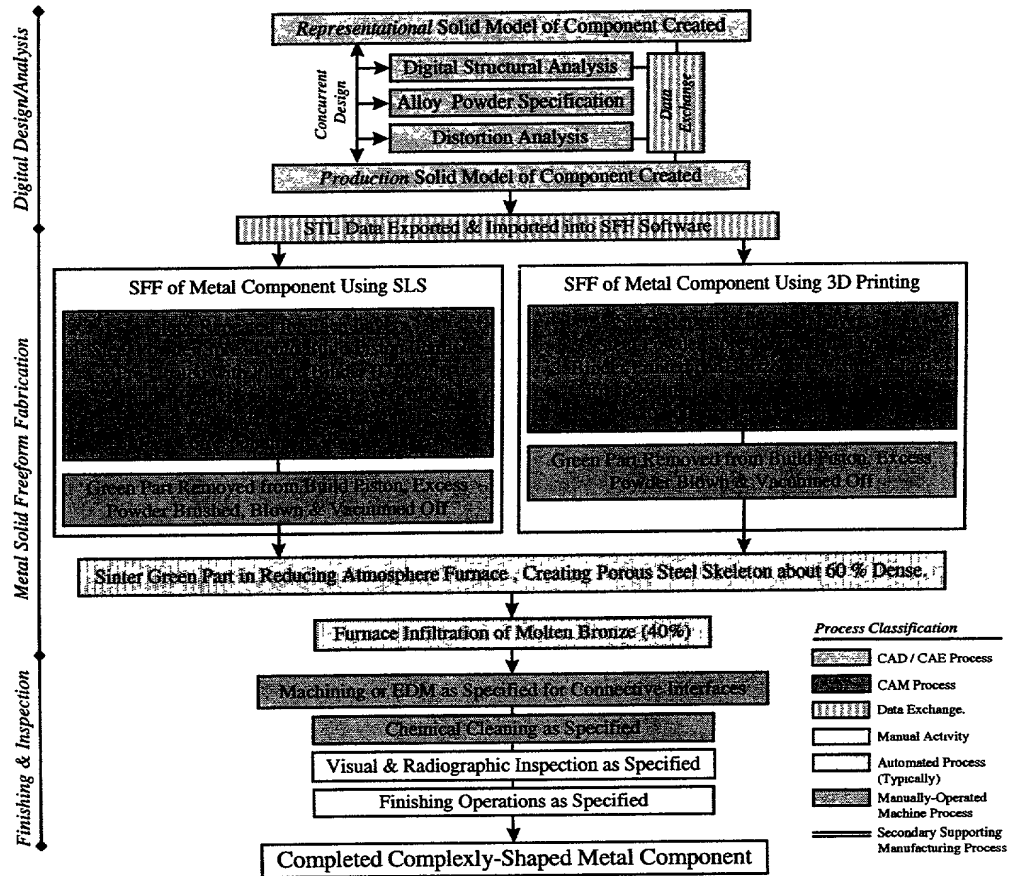


FIG. 32